Pennsylvania Greenhouse Gas Inventory

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Greenhouse Gas Inventory Overview

Global climate is changing due to increased concentrations of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and ozone (O_3) in Earth's atmosphere during the last century. Pennsylvania's climate has undergone a long-term warming of more than 1° C (1.8° F) over the past 110 years. These changes in GHG concentrations and global climate have been linked to human activities, and are long-lasting, as most GHGs take decades to break down and leave the atmosphere.

The Pennsylvania Climate Change Act (Act 70 of 2008, or Act) requires the Department of Environmental Protection (DEP) to develop an inventory of GHGs, and update this inventory annually.

Pennsylvania has several sectors which contribute to GHG emissions, and each of these sectors has undergone fluctuations since the year 2000. Changes in amount and type of fuel consumption, growth and contraction in the economy, and duration of severe weather events all have a role in the trends observed in the Commonwealth's GHG emissions.

The following sectors emit GHGs in Pennsylvania: residential, commercial, industrial, transportation, electricity production, agriculture, waste management, forestry and land use. Data for this inventory were primarily obtained from the United States Environmental Protection Agency (EPA) State Inventory Tool (SIT). SIT is an interactive spreadsheet model designed to help states develop GHG emissions inventories and provides a streamlined way to update an existing inventory or complete a new inventory.

The SIT consists of 11 estimation modules applying top-down approach to calculate GHG emissions, and one module to synthesize estimates across all modules. The default data are gathered by federal agencies and incorporate reported data from private, state, and local sources covering fossil fuels, electricity consumption, agriculture, forestry, waste management, and industry. As is customary, the units for the GHG emissions are given in million metric tons of carbon dioxide equivalent ($MMTCO_2e$). A metric ton is equal to 2,204.6 pounds or approximately 1.1 short tons (US tons). The greenhouse gases typically accounted for in the SIT are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Each GHG has a different global warming potential (GWP), which is accounted for when converting emissions to $MMTCO_2e$. The default GWP used by the SIT for CO_2 is 1.0, CH_4 = 25, and N_2O = 298. The GWP of a GHG will vary depending on the time scale selected. The default time scale for the SIT is 100 years. In order to provide consistency with previous updates and other state inventories using the SIT, the default values were not changed in compiling the inventory.

As shown in Table 1, the total statewide gross GHG emissions for Pennsylvania in 2015, the latest year with complete data available from the SIT, were 286.78 $MMTCO_2e$. Pennsylvania's Forestry and Land Use sector provides a carbon sink for GHG emissions, absorbing approximately 30.73 $MMTCO_2e$ in 2015, and lowering the Commonwealth's net GHG emission for 2015 to 256.05 $MMTCO_2e$. Table 1 also shows a relative decrease of 11.7 percent in the gross emission and 14.4 percent in the net emission totals for 2015 relative to 2000.

Also shown in Table 1, the sectors with the largest contribution to the commonwealth's GHG emissions are the transportation, industrial, and electricity production sectors. The relative change for each of these sectors between 2000 and 2015 was a decrease of 10.63 $MMTCO_2e$ for the transportation sector, an increase of 4.64 $MMTCO_2e$ for the industrial sector, and a decrease of 29.76 $MMTCO_2e$ for the electricity production sector. Together, these three sectors annually account for over 81 percent of Pennsylvania's GHG emissions.

The residential, commercial, and agriculture sectors also experienced declines in GHG emissions during the time period from 2000 to 2015. The residential, commercial, and agriculture sectors had decreases in GHG emissions of approximately 5, 1.5, and 0.05 $MMTCO_2e$, respectively, during this time period.

GHG emissions from the waste management sector experienced an approximately 4.29 MMtCO2e increase from 2000 to 2015. During this same period, the GHG emissions sequestered in the forest and land use sector have increased by approximately 5.13 $MMTCO_2e$.

A brief discussion of each individual sector will occur later in the document. The discussion will focus on the trends of various components within each sector, such as fuel mix or subgroups of the sector.

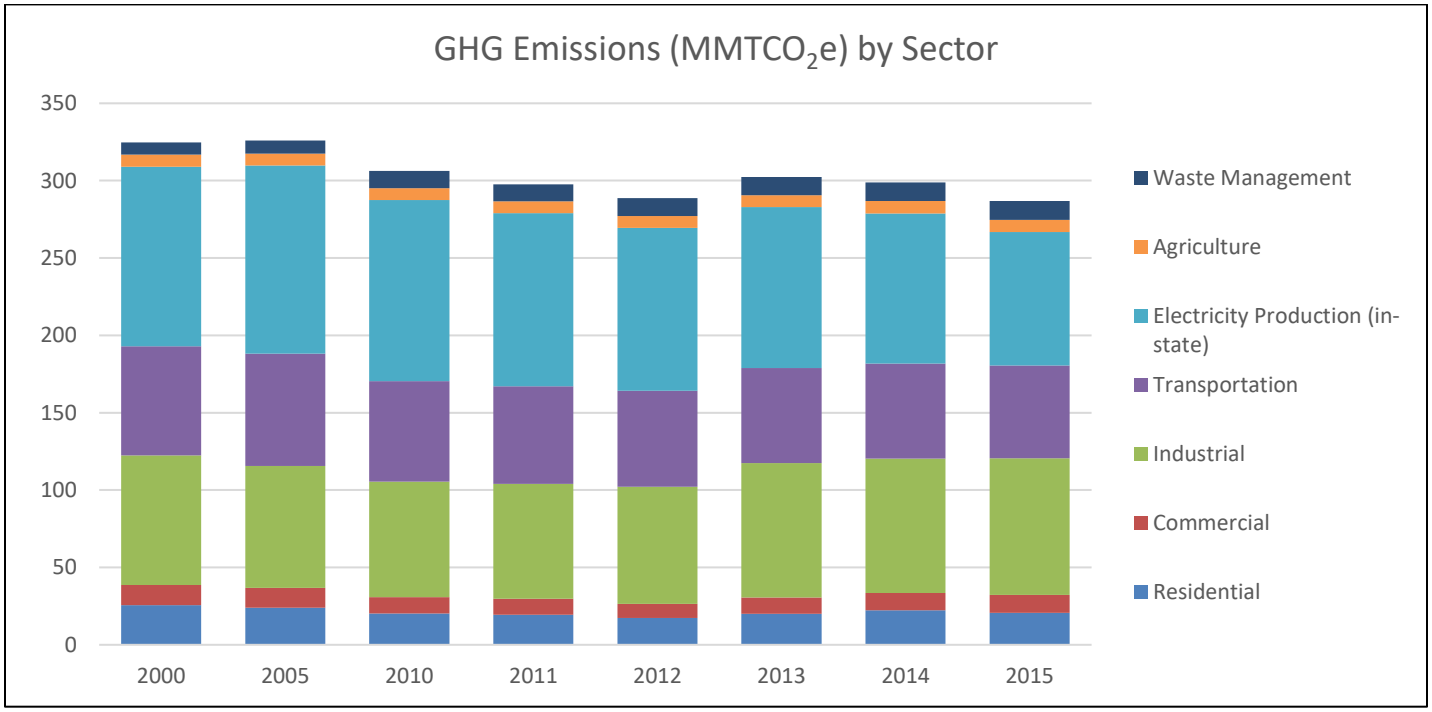
Table 1 - GHG Emissions by Sector

Sector / Emission Sources ($MMTCO_2e$)	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Residential	**25.71**	**23.91**	**20.21**	**19.44**	**17.29**	**20.04**	**22.26**	**20.71**
Commercial	**12.96**	**12.94**	**10.57**	**10.33**	**9.08**	**10.50**	**11.21**	**11.46**
Industrial	**83.69**	**78.78**	**74.76**	**74.28**	**75.83**	**86.87**	**86.9**	**88.33**
Combustion of Fossil Fuels	48.91	46.42	40.54	40.98	42.45	49.45	51.25	52.65
Industrial Process	15.48	13.68	13.33	13.42	13.38	13.9	14.29	14.39
Coal Mining and Abandoned Mines	13.74	10.16	12.54	9.83	9.79	11.25	10.67	10.52
Natural Gas and Oil Systems	5.56	8.52	8.35	10.05	10.21	10.08	10.69	10.77
Transportation	**70.60**	**72.66**	**64.90**	**62.98**	**62.08**	**61.55**	**61.37**	**59.97**
Petroleum	68.46	70.94	62.27	60.14	60.0	59.42	59.0	57.55
Natural Gas	2.13	1.71	2.63	2.84	2.08	2.12	2.37	2.42
Electricity Production (in-state)	**116.13**	**121.57**	**117.14**	**111.94**	**105.24**	**103.88**	**97.08**	**86.37**
Coal	111.04	112.34	102.7	94.32	82.93	83.08	74.68	61.38
Petroleum	3.37	4.19	0.51	0.4	0.26	0.29	0.54	0.44
Natural Gas	1.13	4.43	13.38	16.71	21.59	20.04	21.45	24.20
N_2O	0.554	0.564	0.513	0.473	0.417	0.416	0.376	0.313
CH_4	0.037	0.039	0.037	0.036	0.033	0.032	0.031	0.028
Agriculture	**7.77**	**7.57**	**7.62**	**7.61**	**7.68**	**7.70**	**7.95**	**7.72**
Enteric Fermentation	3.51	3.37	3.44	3.43	3.44	3.45	3.53	3.44
Manure Management	1.285	1.38	1.37	1.38	1.38	1.33	1.41	1.42
Agricultural Soil Management	2.98	2.82	2.80	2.87	2.87	2.91	3.0	2.86
Burning of Agricultural Crop Waste	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Waste Management	**7.93**	**8.55**	**11.12**	**11.03**	**11.55**	**11.73**	**12.03**	**12.22**
Solid Waste and Combustion	6.23	6.85	9.29	9.55	9.79	10.03	10.27	10.46
Waste Water	1.7	1.7	1.74	1.75	1.76	1.7	1.76	1.76
Total Statewide Gross Emissions (Prod)	**324.79**	**325.98**	**306.32**	**297.61**	**288.75**	**302.27**	**298.8**	**286.78**

Increase relative to 2000		0.37%	-5.69%	-8.37%	-11.1%	-6.9%	-8.0%	-11.7%
Forestry and Land Use	-25.60	-34.10	-30.47	-30.53	-30.49	-30.61	-30.73	-30.73
Total Statewide Net Emissions (Prod w/ Sinks)	299.19	291.88	275.85	267.08	258.26	271.66	268.07	256.05
Increase relative to 2000		-2.44%	-7.8%	-10.7%	-13.7%	-9.2%	-10.4%	-14.4%

Figure 1 displays the total contribution to the Commonwealth's GHG emissions for the residential, commercial, industrial, transportation, electricity production, agriculture, and waste management sectors.

Figure 1– GHG Emissions by Sector ($MMTCO_2e$)



Greenhouse Gas Emissions by Sector

Residential Sector

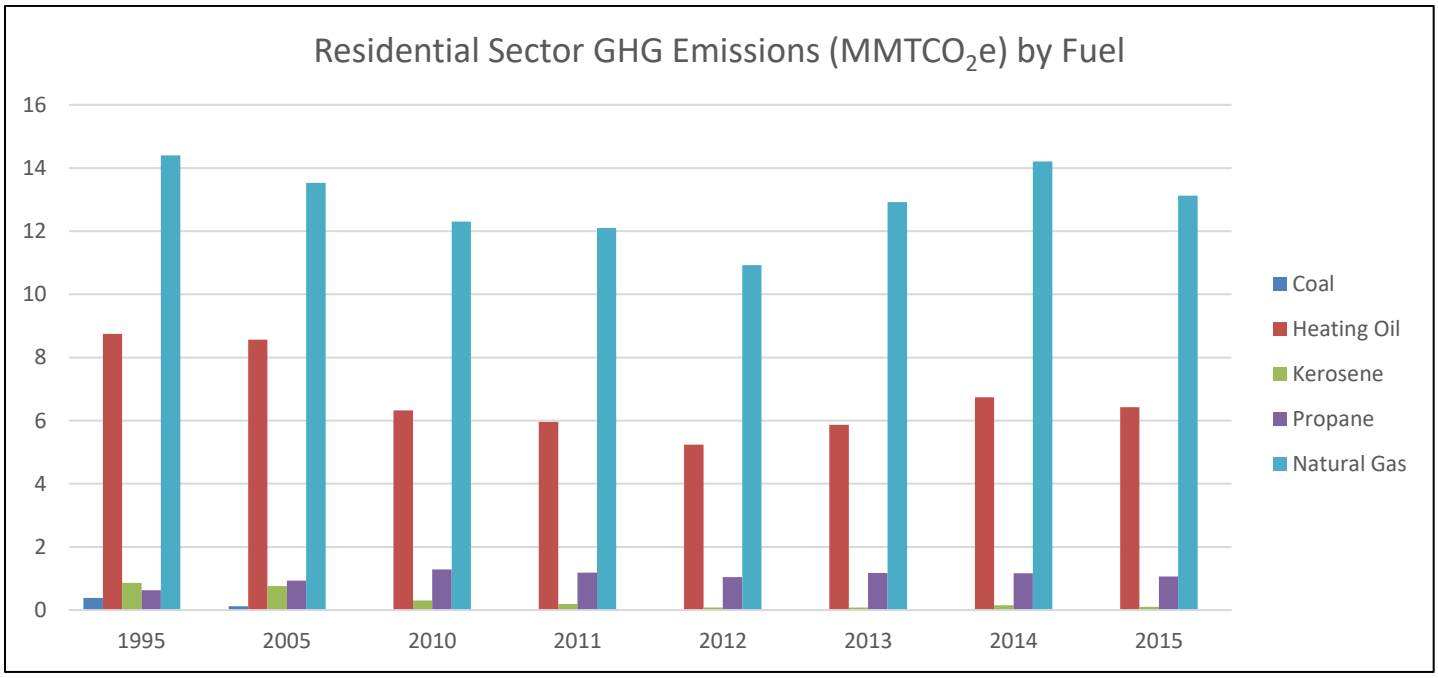
The emissions attributed to the residential sector result from fuels combusted to provide heat and hot water to residential homes within the Commonwealth. These fuels, in order of decreasing use in 2015, are natural gas, heating oil, propane, and kerosene. Table 2 shows the amount of each fuel used (BBtu, or billion British thermal units) in residential homes within the Commonwealth. Several factors have an effect on the amount of a fuel being used; including the severity of the weather, efficiency of the heating/hot water system, and the price/availability of a particular fuel. No electricity consumption is included in these values.

Table 2– Residential Sector Fuel Consumption (BBtu) by Year

	1990	1995	2000	2005	2010	2012	2013	2014	2015
Coal	6,570	3,836	2,154	1,253	0	0	0	0	0
Heating Oil	117,704	118,190	121,678	115,753	85,462	70,830	79,378	91,125	86,879
Kerosene	7,810	11,702	15,822	10,330	4,211	1,076	1,152	2,030	1,350
Propane	8,286	10,107	14,687	15,102	20,815	16,902	18,976	18,832	17,232
Natural Gas	249,467	271,374	271,994	255,038	231,854	205,991	243,891	267,748	247,363

Each fuel used in residential homes will emit GHGs at different rates. Figure 2 shows the GHG emission ($MMTCO_2e$) attributed to each fuel used in the residential sector. The emissions from burning firewood to heat residential homes are accounted for in the land use change sector. The emissions related to electricity use for residential homes using electricity for heating or cooling purposes are accounted for in the electricity production sector.

Figure 2 - Residential Sector GHG Emissions by Fuel Type ($MMTCO_2e$)



Commercial Sector

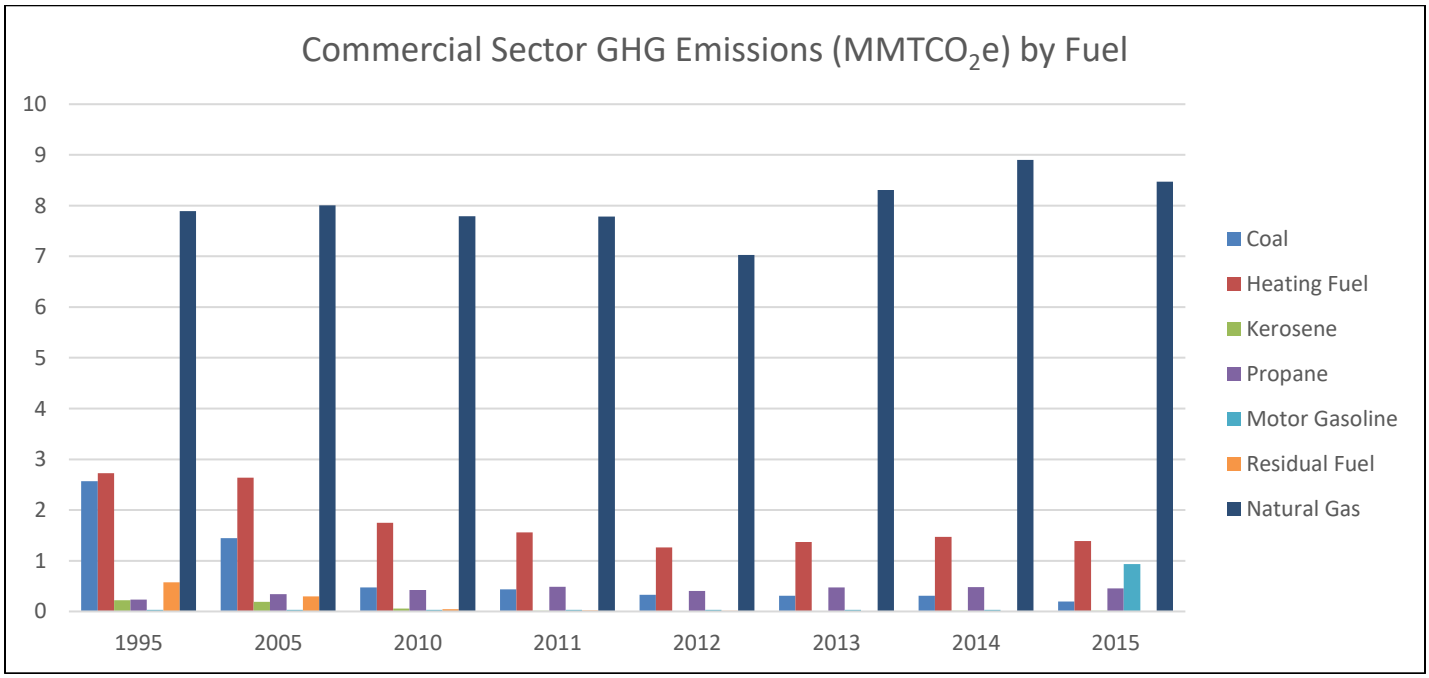
The emissions attributed to the commercial sector result from fuels combusted to provide heat and hot water to commercial buildings within the Commonwealth. These fuels, in order of decreasing use in 2015, are natural gas, heating oil, gasoline, propane, coal, kerosene, and residual oil. Table 3 shows the amount of each fuel used (billion Btu) in commercial buildings within the Commonwealth. Several factors will have an effect on the amount of a fuel being used; including the severity of the weather, efficiency of the heating/hot water system, and the price/availability of a particular fuel. No electricity consumption is included in these values.

Table 3- Commercial Sector Fuel Consumption (BBtu)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Coal	26,279	25,669	17,427	14,407	4,729	4,343	3,286	3,073	3,082	1,963
Heating Oil	38,676	36,862	31,978	35,632	23,638	21,063	17,103	18,541	19,856	18,785
Kerosene	851	2,992	2,307	2,610	755	198	67	58	212	144
Propane	3,143	3,834	5,571	5,473	6,865	7,907	6,540	7,713	7,767	7,385
Motor Gasoline	3,683	453	761	463	429	426	421	434	417	13,087
Residual Fuel	4,992	7,679	3,985	3,934	570	254	163	66	79	53
Natural Gas	130,622	148,806	150,410	150,849	146,902	146,752	132,519	156,594	167,738	159,648

As in the residential sector, each fuel used in commercial buildings will have different rates of GHG emissions. Figure 3 shows the GHG emissions ($MMTCO_2e$) attributed to each fuel used in the commercial sector. The emissions from burning firewood to heat commercial buildings are accounted for in the forestry and land use sector. The emissions related to electricity use for commercial buildings using electricity for heating or cooling purposes are accounted for in the electricity production sector.

Figure 3– Commercial Sector GHG Emissions by Fuel Type ($MMTCO_2e$)



Industrial Sector

Greenhouse gas emissions from the industrial sector differ from the residential and commercial sectors in that the emissions come from four separate sub-groups: combustion of fossil fuels, the industrial process, activities involving coal mining and abandoned coal mines, and activities involving natural gas and oil systems. Within the four sub-groups, combustion of fossil fuels consistently accounts annually for over 50 percent of the GHG emissions from the industrial sector.

Combustion of Fossil Fuels in the Industrial Sector

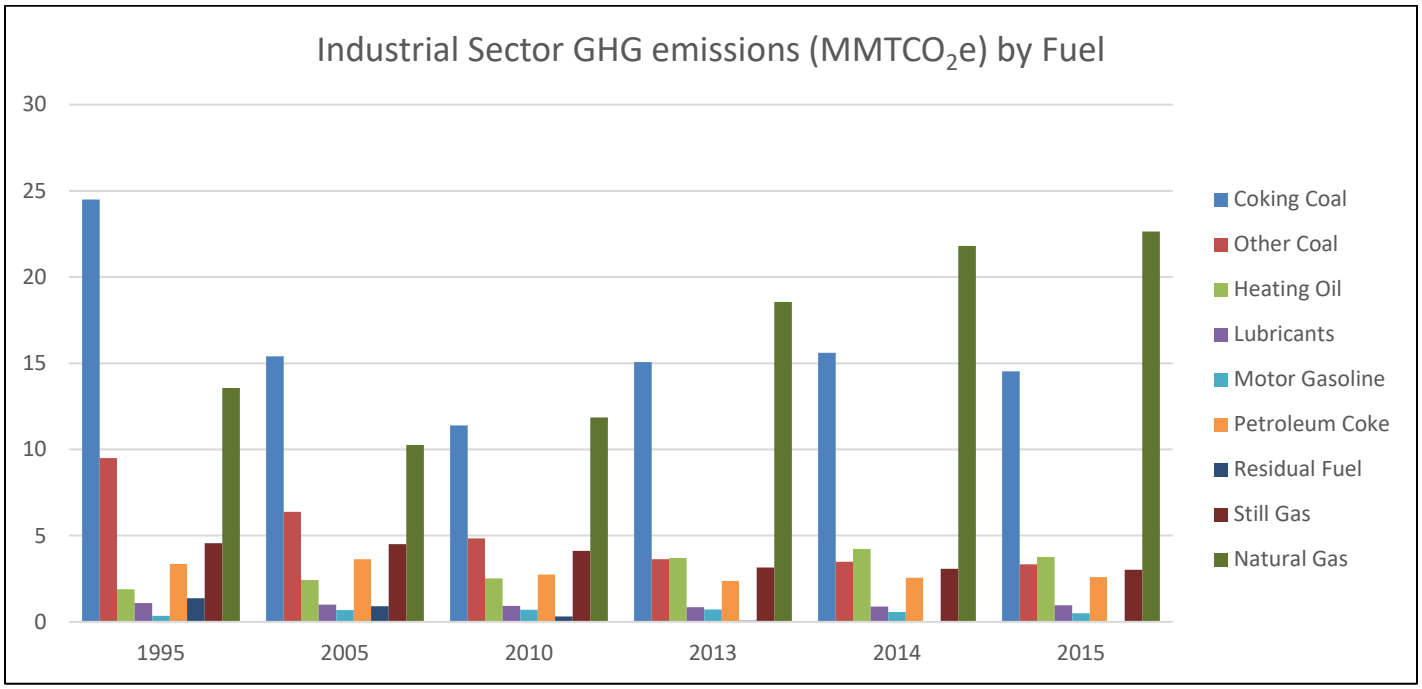
The emissions attributed to the industrial sector result from fuels combusted to heat and cool industrial buildings and equipment within the Commonwealth. These fuels, in order of decreasing use in 2013, are natural gas, coal/coke, heating oil, coal, and various other fuels. Table 4 shows the amount of each fuel used (BBtu) in the industrial sector within the Commonwealth. Several factors will influence the amount of a fuel being used, including the severity of the weather, efficiency of the heating/cooling system, and the price/availability of a particular fuel.

Table 4 – Industrial Sector Fuel Consumption (BBtu)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Coking Coal	280,218	261,897	173,020	164,228	121,445	119,431	132,211	160,754	166,430	154,994
Other Coal	101,704	101,143	85,359	67,654	51,240	47,564	38,897	38,584	38,869	35,377
Heating Oil	43,482	25,496	32,294	32,926	34,119	40,766	45,537	50,149	57,176	51,013
Propane	6,641	3,436	3,313	12,030	12,464	13,026	11,277	9,695	9,415	8,861
Lubricants	15,577	14,861	15,875	13,392	12,495	11,855	10,907	11,541	12,033	13,109
Petroleum Coke	31,513	32,927	32,961	34,433	25,763	20,099	23,758	23,189	25,031	25,424
Residual Fuel	36,050	18,158	12,538	12,039	4,272	4,376	1,287	874	493	565
Still Gas	71,842	68,368	66,807	67,662	61,778	58,929	38,293	46,680	45,818	45,218
Natural Gas	245,738	255,702	237,183	193,374	223,481	251,294	288,558	350,292	379,325	435,853

As in the residential and commercial sectors, each fuel used in the industrial sector emits GHGs at different rates. Figure 4 shows the GHG emissions ($MMTCO_2e$) attributed to each fuel used in the industrial sector. The emissions related to electricity within the industrial sector are accounted for in the electricity production sector.

Figure 4– Industrial Sector GHG Emissions by Fuel Type ($MMTCO_2e$)



Industrial Process

Some of the industrial processes that are accounted for in this group include: cement manufacturing, lime manufacturing, limestone and dolomite use, iron and steel production, substitutes for ozone-depleting substances (ODS), and electric power transmission and distribution systems. The GHG emissions attributed to ODS substitutes are determined using a national emission total and then assigning a state value based on population. For example, in 2013 the United States experienced approximately 154.7 $MMTCO_2e$ of GHG emissions in the production and use of ODS substitutes. Pennsylvania's population in 2013 was 4.04 percent of the national population; therefore, 4.04 percent of 154.7 $MMTCO_2e$ (6.25 $MMTCO_2e$) was assigned to Pennsylvania's inventory. Table 5 shows the GHG emissions ($MMTCO_2e$) attributed to each of the processes included within the industrial sector.

Table 5– Industrial Sector Process Emissions ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Cement Manufacture	2.66	3.08	3.36	3.13	1.65	1.63	1.74	1.87	1.98	1.85
Lime Manufacture	1.13	1.07	1.19	0.85	1.72	1.79	1.68	1.65	2.0	2.20
Limestone and Dolomite Use	-	0.58	0.39	0.55	0.87	0.81	0.59	0.75	0.94	0.95
Iron & Steel Production	-	-	6.33	4.48	6.44	6.65	6.66	6.82	6.00	3.80
ODS Substitutes	0.01	1.42	3.36	4.17	5.80	5.94	6.11	6.25	6.48	6.72
Electric Power Transmission and Distribution Systems	0.98	0.78	0.50	0.33	0.23	0.24	0.19	0.18	0.19	0.16
Total	**4.78**	**6.93**	**15.13**	**13.51**	**16.73**	**17.06**	**16.97**	**17.52**	**17.59**	**15.68**

Please note that tracking of GHG emissions for limestone and dolomite use did not begin in the Commonwealth until 1994 and for iron and steel production until 1997.

Coal Mining and Abandoned Coal Mines

The GHG emissions associated with coal mining, both underground and surface mines, and processing coal are accounted for in this section. The GHG emissions coming from abandoned coal mines are also included. The majority of emissions come from underground mining activity. The results are determined by measurements of ventilation air from underground mines and by applying emission factors for surface mines, abandoned mines, and for coal processing. Table 6 shows the GHG emissions ($MMTCO_2e$) attributed to underground and surface coal mining, coal processing, and abandoned underground mines.

Table 6– Coal Mining-Related Process Emissions ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Underground Mining	7.98	9.91	9.57	6.64	9.39	6.69	6.89	8.56	7.83	8.0
Surface Mining	1.65	1.14	0.97	0.73	0.61	0.67	0.54	0.50	0.45	0.36
Underground Processing	0.86	0.88	1.23	1.16	1.01	1.01	0.96	0.90	1.12	.93
Surface Processing	0.27	0.18	0.16	0.12	0.10	0.11	0.09	0.08	0.07	0.06
Abandoned Mines	0.50	1.24	0.84	0.87	0.66	0.64	0.62	0.61	0.60	0.59
Total	**11.25**	**13.35**	**12.78**	**9.52**	**11.78**	**9.11**	**9.10**	**10.63**	**10.64**	**9.94**

Natural Gas and Oil Systems

The GHG emissions associated with natural gas production, transmission, and distribution are accounted for in this section. Emission factors are used in determining the total GHG emissions based on the number of natural gas wells, miles of transmission pipeline, and the number and types of services used for distribution in the Commonwealth. The natural gas transmission data became available in 2001 while the distribution data became available in 1997. DEP began to collect site-specific emission data from natural gas production in 2010. In order to provide consistency from previous years, this inventory continues to use default SIT emission factors for natural gas production for all years. An emission factor is also used to determine the GHG emissions based on the total oil production within the Commonwealth. Table 7 shows the GHG emissions ($MMTCO_2e$) attributed to natural gas production, transmission, and distribution, and oil production.

Table 7 – Natural Gas Production Process Emissions ($MMTCO_2e$)

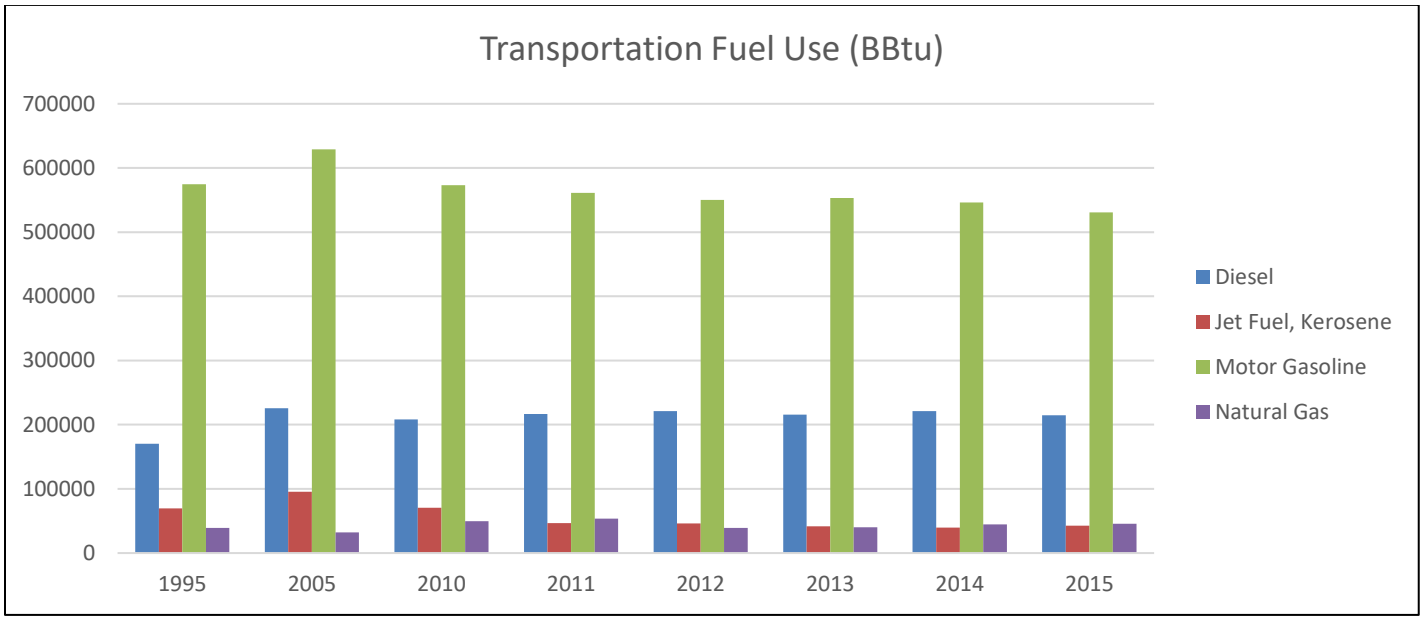
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Natural Gas Production	3.05	3.15	3.67	4.78	4.56	6.34	6.45	6.34	6.93	7.02
Natural Gas Transmission	0.00	0.00	0.00	1.92	1.97	1.89	1.94	1.95	1.96	1.96
Natural Gas Distribution	0.00	0.00	1.89	1.76	1.75	1.75	1.74	1.71	1.7	1.7
Oil Production	0.05	0.04	0.03	0.06	0.07	0.08	0.08	0.09	0.09	0.08
Total	**3.1**	**3.19**	**5.6**	**8.52**	**8.35**	**10.06**	**10.21**	**10.09**	**10.68**	**10.76**

Transportation Sector

The emissions attributed to the transportation sector result from fuels combusted to provide transportation for various types of vehicles within the Commonwealth. These fuels, in order of decreasing use in 2015, are gasoline, diesel, jet fuel, and natural gas. Several factors will influence the amount of a fuel being used:

including the mode of transportation, efficiency of the vehicle, and the price/availability of a particular fuel. The emissions related to electricity use in transportation are accounted for in the electricity production sector.

Figure 5– Transportation Sector Fuel Use (BBtu)



As in the previous sectors, each fuel used in transportation will have different rates of GHG emissions. Table 8 shows the GHG emission ($MMTCO_2e$) attributed to each fuel used in the transportation sector.

Table 8– Transportation Sector Emissions by Fuel Consumption ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Diesel	9.99	12.58	14.63	16.70	15.40	16.03	16.34	15.97	16.36	15.87
Jet Fuel, Kerosene	4.81	4.95	7.79	6.89	5.10	3.36	3.35	3.0	2.86	3.08
Motor Gasoline	39.51	40.80	43.23	44.66	40.88	40.04	39.27	39.47	38.34	37.88
Natural Gas	1.90	2.09	2.13	1.71	2.63	2.84	2.08	2.13	2.04	2.42
Total	**56.21**	**60.42**	**67.78**	**69.96**	**64.01**	**62.27**	**61.04**	**60.57**	**59.6**	**59.25**

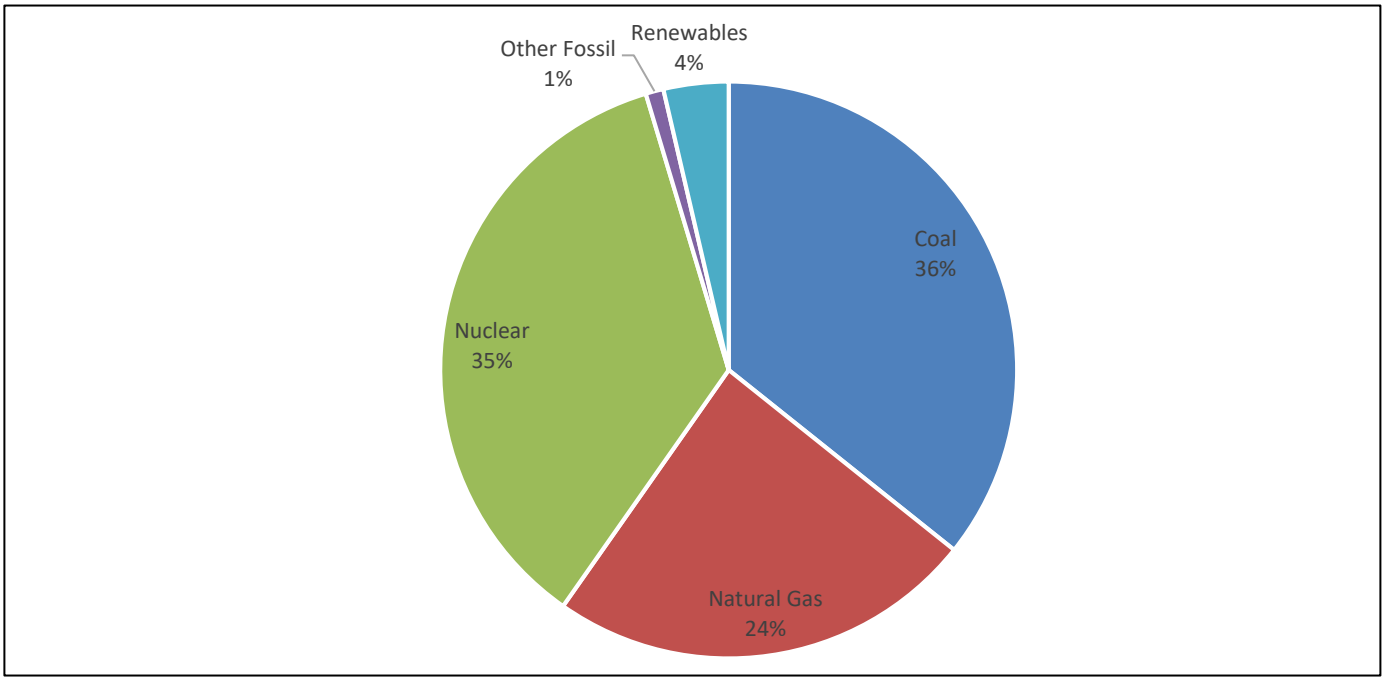
Electricity Production Sector

The emissions attributed to the electricity production sector result from fuels combusted to generate electricity within the Commonwealth. The electricity production sector has historically been the largest contributor of GHG emissions, however, in 2015 the industrial sector became the largest contributor of GHG emissions. Over one third of the statewide gross emissions in 2015 came from the electricity production sector, however, a sizable percentage of these emissions are associated with electricity that is produced and exported to meet the needs of surrounding states. Electricity is produced several different ways within the Commonwealth. The three primary forms of electricity generation in Pennsylvania are coal, nuclear, and natural gas. Figure 6 shows the electricity generation (%) in Pennsylvania by fuel for 2015.
The largest changes in the production of electricity since 1990 have occurred in the use of coal and natural gas. Table 9 gives the relative percentages of each fuel used to generate electricity in Pennsylvania.

Table 9– Electricity Generation by Fuel Type (%)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Coal	60.74%	57.34%	57.62%	55.45%	48.04%	44.26%	39.01%	39.00%	35.73%	35.7%
Hydroelectric	1.63%	1.09%	1.14%	1.02%	1.02%	1.42%	1.00%	1.11%	1.19%	0.9%
Natural Gas	1.61%	2.66%	1.34%	4.96%	14.68%	18.39%	23.75%	22.02%	23.99%	24.0%
Nuclear	32.90%	35.84%	36.58%	34.98%	33.87%	33.50%	33.65%	34.71%	35.61%	35.6%
Other	0.00%	0.02%	0.03%	0.34%	0.37%	0.39%	0.40%	0.37%	0.41%	0.0%
Biomass	0.17%	0.89%	1.00%	0.62%	0.74%	0.73%	0.79%	0.81%	0.86%	1.1%
Other Fossil	0.48%	0.42%	0.30%	0.25%	0.24%	0.27%	0.27%	0.29%	0.22%	0.6%
Oil	2.65%	1.97%	1.86%	2.27%	0.25%	0.19%	0.13%	0.20%	0.36%	0.4%
Solar	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.03%	0.03%	0.03%
Wind	0.00%	0.00%	0.00%	0.13%	0.81%	0.79%	0.95%	1.48%	1.61%	1.61%

Figure 6– Electricity Generation by Type (%) for 2015



Since electricity produced from nuclear fuel, hydroelectric, solar, and wind creates no direct GHG emissions, the primary fuels associated with GHG emissions from electricity production are coal, natural gas, and oil. Table 10 shows the amount of each of these fuels consumed (BBtu) in generating electricity in Pennsylvania.

Table 10– Fuel Use for Electricity Generation (BBtu)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Coal	1,054,707	1,062,368	1,210,638	1,224,911	1,119,758	1,028,374	904,245	905,843	814,266	669,244
Natural Gas	13,972	40,618	21,298	83,531	252,182	314,973	406,963	378,099	404,325	456,219
Oil	54,274	38,544	44,914	51,783	6,813	5,326	3,566	3,908	7,222	6,014

As in the previous sectors, each fuel used in electricity production emits GHGs at different rates. Figure 7 shows the GHG emission ($MMTCO_2e$) attributed to the three primary fuels used in the electricity production sector.

Figure 7– GHG Emissions by Fuel Type

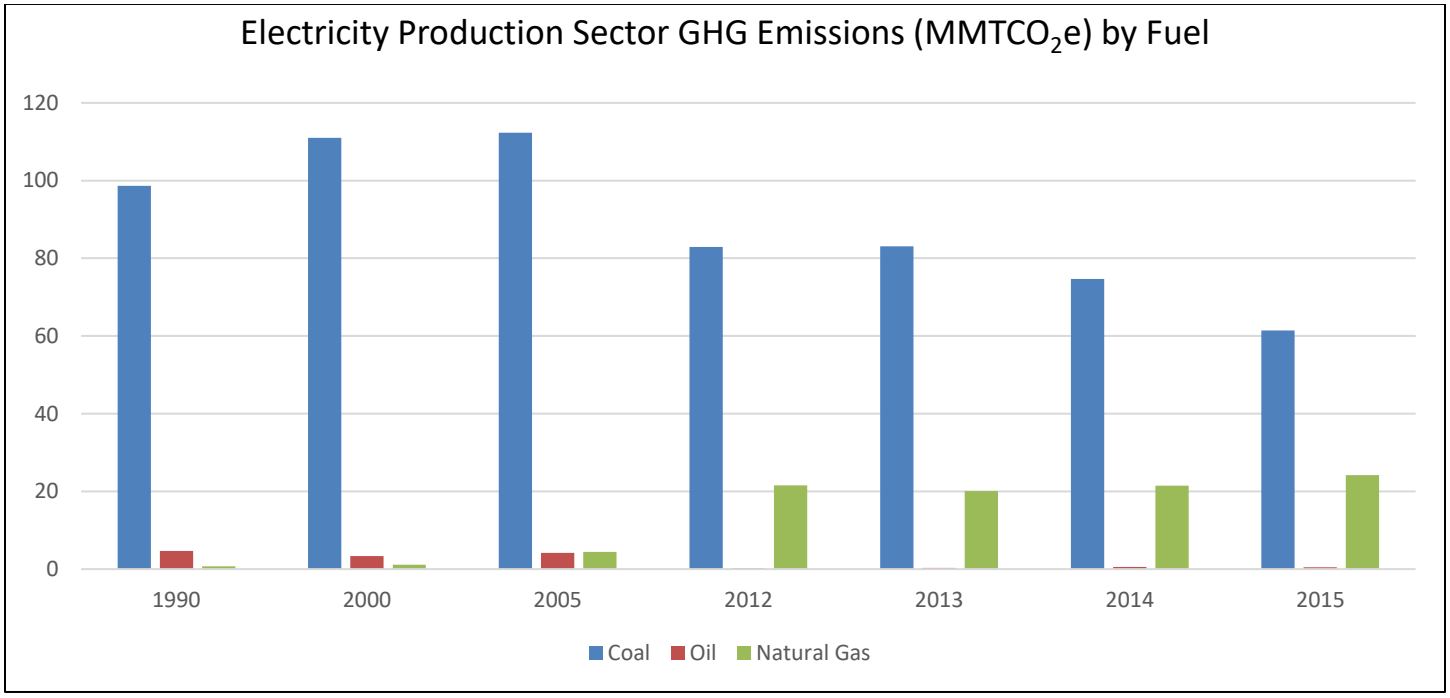


Table 11 gives the relative percentage of GHG emissions attributed to the three primary fuels used in the electricity production sector.

Table 11– Contribution to GHG Emissions, Fuel Type, in the Electricity Sector (%)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Coal	94.8%	94.4%	96.1%	92.9%	88.1%	84.6%	79.1%	80.3%	77.3%	71.3%
Oil	4.5%	3.5%	2.9%	3.5%	0.4%	0.4%	0.3%	0.3%	0.6%	0.5%
Natural Gas	0.7%	2.0%	1.0%	3.7%	11.5%	15.0%	20.6%	19.4%	22.2%	28.1%

As noted in Tables 9 and 11, for Pennsylvania's electricity generation sector in 2015 coal produced over 71 percent of the GHG emissions while producing 35.7 percent of the electricity, natural gas produced approximately 28 percent of the GHG emissions while producing approximately 24 percent of the electricity, oil resources produced just over one-half of one percent of the GHG emissions while producing about four tenths of one percent of all electricity generated in the Commonwealth. Nuclear fuel, which produces no GHG emissions, was responsible for generating 35.6 percent of the electricity.

As has been noted in previous inventory reports, Pennsylvania has historically been, and is projected to remain, an exporter of electricity to neighboring states. Table 12 shows the total consumption of electricity (TWh) within the residential, commercial, industrial, and transportation sectors.

Table 12 – Electricity Consumption by Sector (TWh)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015

Residential	38.17	42.80	45.01	53.66	55.26	54.80	52.88	54.25	54.20	54.42
Commercial	30.20	35.54	42.99	45.78	47.37	43.54	42.92	43.15	43.4	43.75
Industrial	45.99	47.53	45.45	47.95	45.46	49.59	48.04	48.05	48.32	47.41
Transportation	0.40	0.38	0.40	0.88	0.89	0.84	0.88	0.81	0.83	0.76
Line Loss	6.41%	6.41%	6.41%	6.41%	5.82%	5.82%	9.17%	9.17%	4.97%	4.97%
Total	**122.62**	**134.90**	**143.02**	**158.44**	**158.18**	**157.96**	**159.33**	**161.03**	**154.42**	**154.01**

Table 13 gives the total amount of electricity (TWh) consumed in Pennsylvania and the total amount of electricity (TWh) generated. The difference between the two values is the total amount of electricity (TWh) exported from Pennsylvania.

Table 13– Electricity Generated, Consumed and Exported (TWh)

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Electricity Consumed	122.62	134.90	143.02	158.44	158.18	157.96	159.33	161.03	154.42	154.01
Electricity Generated	175.62	185.45	201.69	218.09	229.75	227.31	223.42	226.79	222.06	221.04
Electricity Exported	53.01	50.55	58.67	59.66	71.57	69.35	64.09	65.76	67.63	67.03

Agriculture Sector

At consistently less than eight $MMTCO_2e$ annually, the GHG emissions from the agriculture sector are significantly lower than emission from the industrial, transportation, and electricity production sectors. Like the industrial sector, GHG emissions in the agriculture sector are broken down into smaller groups: enteric fermentation, manure management, and soil management. Table 14 lists the number (1,000 head) of each type of farm animal accounted for in the SIT.

Table 14– Animal Populations Contributing to GHG Emissions (1,000 Head)

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Dairy Cows	694	639	619	566	540	543	540	535	530	530
Dairy Replacement Heifers	285	275	285	275	300	310	315	310	315	305
Beef Cows	166	171	151	154	160	167	160	155	140	150
Beef Replacement Heifers	39	42	35	40	40	40	45	55	50	50
Heifer Stockers	28	24	20	55	50	50	55	0	40	60
Steer Stockers	199	188	165	170	150	130	145	170	185	145
Feedlot Heifers	22	25	25	24	24	24	24	24	24	24
Feedlot Steer	44	47	44	44	46	46	46	46	46	46
Bulls	29	27	25	25	25	25	25	25	25	25
Sheep	134	110	90	100	100	98	89	86	86	86
Goats	10	23	37	52	54	52	50	48	48	48
Swine	920	1,000	1,030	1,100	1,110	1,120	1,140	1,080	1,055	1,160
Horses	61	83	108	115	118	119	120	121	121	121

The enteric fermentation group includes animals that produce methane emissions as a result of their unique digestive process. Each type of farm animal has an associated methane emission factor associated with the enteric fermentation process. The total estimated GHG emissions from enteric fermentation then is a summation of the product of the size of the statewide herd of each particular farm animal and the emission

factor for that animal. Table 15 shows the GHG emissions ($MMTCO_2e$) attributed to each animal in the agriculture sector due to enteric fermentation.

Table 15– GHG Emissions, by Livestock Type, from Enteric Fermentation ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Dairy Cows	2.253	2.098	2.136	1.936	1.949	1.960	1.949	1.931	1.913	1.932
Dairy Replacement Heifers	0.492	0.452	0.471	0.440	0.495	0.511	0.519	0.511	0.519	0.503
Beef Cows	0.366	0.388	0.341	0.357	0.402	0.419	0.402	0.389	0.402	0.354
Beef Replacement Heifers	0.058	0.066	0.055	0.065	0.071	0.071	0.080	0.098	0.089	0.089
Heifer Stockers	0.035	0.033	0.030	0.082	0.080	0.080	0.088	0.000	0.064	0.090
Steer Stockers	0.270	0.264	0.240	0.245	0.233	0.202	0.225	0.264	0.287	0.210
Feedlot Heifers	0.022	0.024	0.025	0.024	0.026	0.026	0.026	0.026	0.026	0.026
Feedlot Steer	0.043	0.043	0.042	0.042	0.048	0.048	0.048	0.048	0.048	0.048
Bulls	0.065	0.063	0.058	0.060	0.065	0.065	0.065	0.065	0.065	0.061
Sheep	0.027	0.022	0.018	0.020	0.020	0.020	0.018	0.017	0.017	0.017
Goats	0.001	0.003	0.005	0.006	0.007	0.006	0.006	0.006	0.006	0.006
Swine	0.035	0.038	0.039	0.041	0.042	0.042	0.043	0.041	0.17	0.044
Horses	0.027	0.037	0.049	0.052	0.053	0.054	0.054	0.054	0.054	0.054
Total	**3.694**	**3.531**	**3.509**	**3.370**	**3.491**	**3.504**	**3.523**	**3.450**	**3.660**	**3.434**

The second sub-group of the agriculture sector is the manure management group. As with the enteric fermentation sub-group, each type of farm animal has an associated emission factor for the GHG emission (CH_4 and N_2O) based on the amount of manure that the animal produces. The total GHG emissions from manure management are equal to the summation of the product of the statewide livestock herd size, by animal and the emission factor for that animal. Table 16 shows the GHG emission ($MMTCO_2e$) attributed to each animal in the agriculture sector due to manure management. The "other" category includes sheep, goats, and horses.

Table 16 – GHG Emissions, by Livestock Type, from Manure Management ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Dairy Cattle	0.598	0.578	0.640	0.658	0.639	0.644	0.643	0.637	0.409	0.74
Beef Cattle	0.048	0.049	0.048	0.048	0.050	0.050	0.051	0.049	0.022	0.058
Swine	0.247	0.290	0.273	0.318	0.324	0.323	0.322	0.314	1.123	0.323
Poultry	0.229	0.236	0.211	0.227	0.210	0.210	0.209	0.220	0.04	0.148
Other	0.006	0.008	0.010	0.010	0.011	0.011	0.011	0.011	0.011	0.012
Total	**1.129**	**1.162**	**1.183**	**1.262**	**1.235**	**1.239**	**1.237**	**1.231**	**1.605**	**1.281**

The third sub-group of the agriculture sector is the soil management group. GHG emissions (N_2O) from agricultural soils are calculated from the direct and indirect biochemical interactions of fertilizers, livestock, and crop residue with the soil. Table 17 below shows the estimated GHG emissions ($MMTCO_2e$) resulting from agriculture soils management.

Table 17 – GHG Emissions from the Management of Agricultural Soils ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Direct	2.16	2.16	2.24	2.13	2.13	2.12	2.19	2.05	2.49	2.38

Indirect	0.41	0.44	0.44	0.42	0.42	0.42	0.43	0.38	0.22	0.21
Total	**2.57**	**2.60**	**2.67**	**2.55**	**2.55**	**2.54**	**2.61**	**2.43**	**2.71**	**2.59**

Waste Management Sector

GHG emissions in the waste management sector primarily come from three sub-groups; landfill gas, solid waste combustion, and wastewater treatment. Landfill gas, which is approximately 50 percent methane, is generated by the decomposition of solid waste within a landfill. Some solid waste in the Commonwealth is combusted in waste-to-energy plants, avoiding the production of methane that would otherwise be produced in a landfill but which also results in the release of carbon dioxide. Both municipal wastewater treatment and industrial wastewater treatment are accounted for in the third sub-group.

Data in the SIT regarding the amount of landfilled solid waste in the Commonwealth was used to calculate the potential landfill methane emissions. Future reports may include landfill gas data provided to DEP by landfill operators. The methane avoided value in Table 18 was calculated using data in the SIT and reflects the amount of methane that otherwise could have entered the atmosphere, but instead was combusted in either a flare or a landfill gas to energy project. A small amount (10 percent) of the landfilled solid waste was assumed to oxidize each year and thus would not be contributing to the amount of methane emitted. Table 18 shows the GHG emissions ($MMTCO_2e$) attributable to the potential landfill gas, the avoided methane emissions, and the avoided emissions due to solid waste oxidation.

Table 18– GHG Emissions Associated with Landfilling Operations ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Potential Landfill CH_4	8.104	8.511	8.552	8.805	10.019	10.265	10.501	10.728	10.946	11.156
CH_4 Avoided	0.000	-0.475	-2.840	-2.988	-2.210	-2.210	-2.210	-2.210	-2.210	-2.210
Oxidation	0.810	0.804	0.571	0.582	0.781	0.805	0.829	0.852	0.874	0.895
Total CH_4 Emissions (Landfills)	**7.294**	**7.232**	**5.141**	**5.235**	**7.028**	**7.249**	**7.462**	**7.666**	**7.862**	**8.051**

The GHG emissions in the solid waste combustion sub-group result from the combustion of certain types of solid waste (plastics, synthetic rubber, and synthetic fibers). To avoid the potential for double counting, the emissions from the combustion of natural or biogenic materials, such as cotton, paper, etc. are omitted because these items would decompose naturally and therefore, no additional CO_2 is emitted from the combustion of these materials. This section also accounts for N_2O and CH_4 gases that are generated in the waste combustion process. Data from the SIT for total solid waste combusted and the relative percentage of each of the materials listed previously was used in the calculation. Table 19 shows the GHG emissions ($MMTCO_2e$) attributable to the combustion of plastics, synthetic rubber, and synthetic fibers of the waste combustion portion of the waste management sector.

Table 19– GHG Emissions Associated with Waste Combustion ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
CO_2	0.222	0.670	1.059	1.580	2.213	2.256	2.280	2.323	2.361	2.361
N_2O	0.008	0.021	0.027	0.034	0.043	0.043	0.043	0.043	0.043	0.043
CH_4	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total CO_2, N_2O, CH_4 Emissions (Waste Combustion)	**0.231**	**0.692**	**1.087**	**1.615**	**2.257**	**2.300**	**2.325**	**2.367**	**2.405**	**2.405**

The GHG emissions from the wastewater portion of the waste management sector are a combination of municipal wastewater treatment (CH_4 and N_2O) and some types of industrial wastewater treatment (red meat, poultry, pulp and paper). The SIT was used to calculate the municipal and industrial wastewater GHG emissions. Production data was collected for the poultry, pulp, and paper industrial wastewater treatment sector and multiplied by the SIT-supplied emission factors to determine the total GHG emissions. Table 20 shows the GHG emissions ($MMTCO_2e$) attributed to the treatment of wastewater from municipal and industrial sources in the waste management sector.

Table 20 – GHG Emissions Associated with Wastewater Treatment ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Municipal CH_4	0.95	0.96	0.98	0.99	1.02	1.02	1.02	1.02	1.02	1.02
Municipal N_2O	0.35	0.36	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.39
Industrial CH_4	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total	**1.33**	**1.35**	**1.40**	**1.41**	**1.44**	**1.45**	**1.45**	**1.45**	**1.45**	**1.45**

Table 21 shows the GHG emissions ($MMTCO_2e$) totals for the solid waste and wastewater treatment portions of the waste management sector.

Table 21– Total GHG Emissions from the Waste Management Sector ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Solid Waste	7.52	7.92	6.23	6.85	9.28	9.55	9.79	10.03	10.27	10.46
Wastewater	1.33	1.36	1.40	1.40	1.43	1.45	1.45	1.45	1.45	1.45
Total	**8.85**	**9.28**	**7.63**	**8.25**	**10.71**	**11**	**11.24**	**11.48**	**11.72**	**11.91**

Forestry and Land Use Sector

The forestry and land use sector is very important in its ability to sequester (absorb) carbon dioxide, reducing the net GHG emission in the Commonwealth. In 2015, over 31 $MMTCO_2$ of GHG was sequestered in the forestry and land use sector, more than the GHG emissions from the residential and commercial sectors combined. This sector includes forested lands and soils, liming and fertilization of agricultural soils, trees located in urban settings, yard waste, and forest fires. Data from the SIT was the primary source of information for this section. Table 22 shows the total GHG emissions produced (positive values) and emissions sequestered (negative values) ($MMTCO_2e$) totals for the forestry and land use sector.

Table 22– Total GHG Emissions from the Forestry and Land Use Sector ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Forest Carbon Flux	-23.35	-22.05	-22.05	-29.32	-27.06	-27.06	-27.06	-27.06	-27.06	-27.06
Liming of Agricultural Soils	0.26	0.20	0.19	0.03	0.38	0.19	0.24	0.13	0.17	0.08
Urea Fertilization	0.03	0.03	0.04	0.02	0.03	0.02	0.03	0.03	0.03	0.03
Urban Trees	-2.39	-2.69	-3.00	-3.15	-3.31	-3.34	-3.37	-3.40	-3.43	-3.46
Landfilled Yard Trimmings and Food Scraps	-1.10	-0.61	-0.45	-0.39	-0.43	-0.43	-0.43	-0.42	-0.40	-0.39
Forest Fires	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O from Settlement Soils	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total	**-28.60**	**-27.19**	**-26.05**	**-34.48**	**-30.90**	**-30.96**	**-30.91**	**-31.01**	**-31.00**	**-31.13**